B.C. HYDRO

HOMATHKO DEVELOPMENT

GENERATION

LANDSAT BASED MAPPING OF SNOW COVER AND VEGETATION COVER

PRELIMINARY

by

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1.0 SUMMARY

Satellite imagery has been successfully employed to classify vegetation, to observe landform, and to quantify snow cover. These features were used to infer capability of lands to support wintering ungulates in the Homathko River drainage basin. Landforms and vegetation information are inter-dependent and cannot be easily separated.

Information on snow cover was obtained more or less independently of other factors by utilizing imagery from dates between March and August in different years and comparing the pattern of snow cover as a function of month of the year. Snow cover mapping revealed a complex pattern of melting with a high degree of dependence on local topographic features.

The subalpine, especially at the headwaters of tributary streams, appeared to be more favourable as ungulate winter range than most lower elevation sites. If true, this observation may have a strong bearing on impact assessment.

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2.0 INTRODUCTION AND PROJECT DESCRIPTION

Proposed hydro-electric development could affect the watershed of the Homathko River and concommitantly the wildlife resources within this watershed. The study area, which was defined in the terms of reference in terms of the watersheds of potentially affected rivers, is large (in excess of 13,000 km^2) and environmentally diverse, encompassing portions of five of the eleven biogeoclimatic zones in British Columbia (Krajina, 1973). Satellite imagery has been used to assist the preliminary environmental study of wildlife and wildlife habitat. Figure 1 shows the location of the satellite imagery within the Homathko development scheme.

This report, commissioned by B.C. Hydro on August 9, 1982, summarizes the methodology, results and conclusions of the Landsat based investigation of the Homathko Development Study Area.

The study includes delineation of inferred critical ungulate habitat, digital classification of vegetation within the study area, ground-truthing of that classification, and provision of maps and color imagery of the study area.

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3.0 TERMS OF REFERENCE AND OBJECTIVES

The terms of reference of this study are to use serial analysis of Landsat data to define areas which have potential value as winter range for ungulates, to classify and rank these areas, to describe these areas, and to map these areas at a scale of 1:250 000.

The objective of the proposed study is to delineate environmental features on a regional scale by using the unique capabilities of Landsat imagery. Specifically, multi-date imagery is used to document changes in snow cover and to correlate this snow cover information with terrain and vegetative cover information to discern areas of winter [illegible].

The terms of reference are appended in Appendix A.

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4.0 METHODOLOGY

4.1 Image Acquisition and Precision Processing

Our first step was to obtain a list of all potentially acceptable Landsat MSS imagery of WRS Track 53, Frame 24 (Figure 1) from the Canadian Centre for Remote Sensing (CCRS). Criteria for image selection were:

- virtually cloud-free images;
- fair or preferably good quality rating of imagery;
- one scene from a late winter or early spring date with snow on the ground but not on the trees;
- one scene from the middle of the growing season, preferably August;
- as many scenes as available (at least two) from dates between the winter and the summer scenes;
- images preferably from the same year.

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All criteria could be met except the last one. Few good quality, cloud-free images have been catalogued from coastal B.C. and most of these are during the summer. The critical melt-off period was sparsely represented, so we were forced to employ a multi-temporal analysis in which images are taken from different months and different years rather than the preferred serial analysis, in which the images are all from one year and represent a true temporal series of events.

Four images were selected, one each from the following dates: April 9, 1975, March 19, 1979, May 30, 1979, and August 17, 1981. The image data were acquired from CCRS in the form of computer compatible tapes.

It is essential to compare the same points on the ground when using multi-date imagery. If images from two dates are digitally compared without accurate registration, then measured changes could be either temporal or spatial variation. The objective of this study was to document temporal variation on maps, so special care was taken to remove the spatial effects of misregistration and have all images conform to the base maps.

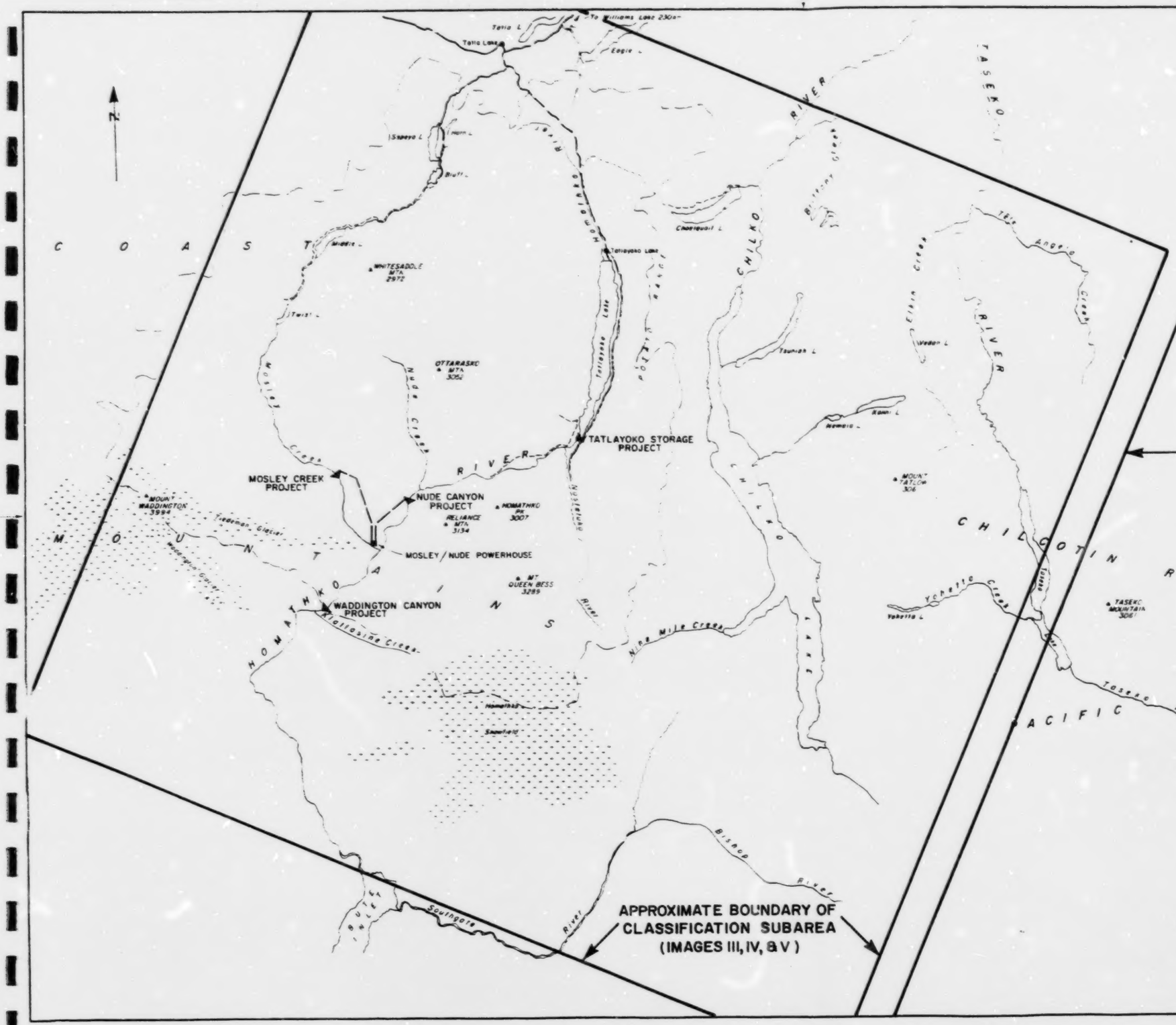

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FIGURE 1

HOMATHKO DEVELOPMENT
AREA LOCATION PLAN
PRELIMINARY LAND SAT STUDIES

Bulk processed Landsat imagery is notably deficient in absolute and relative positional accuracy. Bulk processed Landsat images can be as much as 10 km off center because of minor variations in orbit. Relative distortions of a hundred of metres within a frame occur because of satellite wobble (roll, pitch and yaw) during imaging. "Precision processing" is the term used for the process of removing these geometric errors. A precision processed product can be within 25 m of ground truth if sufficiently accurate maps exist for the area and if good ground control points can be located on the images.

The bulk processed Landsat images obtained for this project were geometrically corrected to match ground control points obtained from 1: 50 000 scale government issue maps and were registered to one another using the image analysis system at MacDonald Dettwiler and Associates (MDA) in Richmond, B.C. MDA uses proprietary software which is among the best in the world to accomplish geometric correction of full scene Landsat data. Radiometric correction preceded geometric correction: stripes caused by sensor inequalities were deemphasized and missing data lines were replaced. The overall result was to produce four images which were virtually identical except for seasonal environmental variations.

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4.2 Snow Cover Analysis

A multi-temporal analysis of changes in the areal extent of snow cover between dates was used to document the pattern of snowmelt. Ideally, the disappearance of snow from the ground should be documented periodically during melt-off in one year. Unfortunately, good imagery all from one year did not exist, so month to month comparisons have been somewhat confused by year to year variations. We expect and have assumed for the sake of analysis that the variation in snow cover between years is minor compared with the variation in snow cover between months. Except for major year-to-year changes such as logging clearcuts, the results of the snow cover mapping appear to be consistent with this assumption for the Homathko Study Area. The pattern of snowmelt which is of interest would be the large scale predictable patterns created by dominant and repeated interactions between weather systems and the mountainous terrain. These patterns

should be evident despite imagery from different years.

The spring scenes are the key to the ungulate winter range analysis as the pattern of snowmelt is related to the food value of the habitat. Shallow snow may be a prerequisite to good winter range for the ungulate species occurring in the study area. Although snow depth cannot be directly measured from Landsat data, the extent of snow cover can. Areas of shallow snow are assumed to melt off faster and become snow-free earlier than adjacent areas of deeper snow. Those areas free of snow first are probably the areas which had the least accumulation and are certainly the areas which green-up first in the spring, and so constitute the most probable winter and early spring range.

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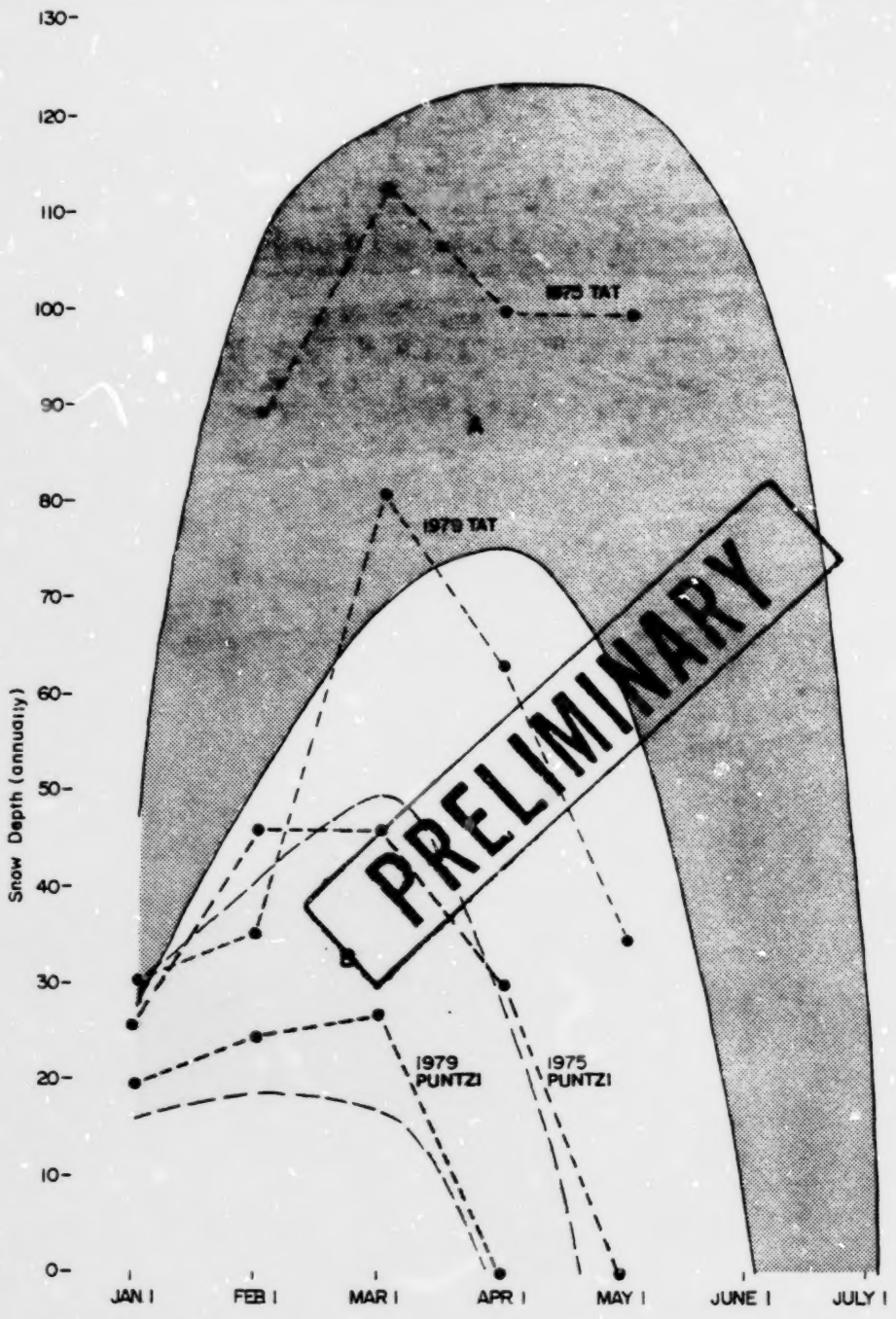
Four separate dates allow three time intervals to be documented: March 19 - April 9; April 9 - May 30; and May 30 - August 17. Snowmelt for each time interval was documented by subtracting the reflectance value for Band 5 for each of the more than 11 million pixels in an image from the corresponding Band 5 value from the earlier date. The result is retained as a difference image for that time interval. These difference images were transformed one at a time into black-and-white photographic output products and combined into a single three-color composite photographic image to be used for visual interpretation.

Analysis of snow course data was used to test the assumption that a multi-year analysis would produce results essentially similar to those from serial analysis. Imagery was acquired from three separate years - 1975, 1979 and 1981. The August 1981 imagery was chosen as the no-snow control, so snowpack conditions for the 1980-81 winter are of no concern. A comparison of snow course data (Ministry of Environment, 1980) from Tatlayoko Lake and Puntzi Mountain shows that 1975 was a fairly typical year (Figure 2). In contrast, 1979 was a low snow year. The sequence of dates analysed was March 1979, April 1975, May 1979, and August 1981. Any differences between March and May of 1979 are real. The use of data from April of a year in which snow cover was "average" but heavier than 1979 would produce a snowmelt pattern for April typical of an "average" year and a snow year pattern for May typical of a light snow year. An apparent



Note: At either location, measurements above the stippled area represent unusually deep snow, measurements below indicate unusually light snow.

A — Typical Snow depth at Tatlayoko Lake snow course (based on mean ± 1 s.d.)

B — Typical Snow depth at Puntzi Mountain snow course (mean ± 1 standard dev.)

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Summary of Snow Course Measurements for Tatlayoko Lake and Puntzi Mountain, 1952-1980

TO ACCOMPANY REPORT BY D.B. HAWES

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	FILE 55 03	FIGURE 2
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pattern of extremely rapid snowmelt during the April-May interval could occur as an analysis artifact. Any melting after May of a light snow year must be considered indicative of late melting areas. The net effect of the multi-temporal analysis would be to exaggerate melt during the April-May interval while providing a conservative indication of the location of early and late melting areas. This pattern reduces the information content of the snowmelt analysis, but in no way invalidates it.

Another question which the snow course data may help answer is whether or not the assumed correlation between snow depth and time of snowmelt is correct. Snow course data are collected to allow hydrologists to document the maximum snow pack and snow water equivalents. After snowmelt is well on its way, the information value to hydrologists is reduced, so snow course transects are stopped. As a result, snow depth at Tatlayoko Lake has never been recorded until all snow has melted, and has seldom been recorded after May 1. Later records were taken in some years, but one suspects that these are years in which snow cover was especially heavy or late in melting. The data at Puntzi Mountain are much more consistent, but in neither area can the assumption be rigorously tested.

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However, several patterns are detectible from the snow course data (Figure 2). First, at any one location, the generalized pattern of snow depth appears to be correlated with date of meltoff. Second, the correlation is not perfect as a review of individual years shows some combinations in which the pattern is reversed. Third, even if the correlation exists, great changes in snow depth are required to produce small changes in meltoff dates. Fourth, and most significantly, Puntzi Mountain has consistently less snow and earlier meltoff than Tatlayoko Lake. In conclusion, it appears reasonable to expect to see differences in snow depth between sites manifested in differences in meltoff times, but that it would be misleading to conclude that all snow depth differences would be thus manifested.

4.3 Vegetation Classification

Two Landsat scenes, March 19, 1979 and August 17, 1981, were used to classify vegetation. Reflectance values from the March scene were used to make a first iteration separation into two categories. The August scene was used in a second iteration for detailed subclassification. The objective of the first level classification was to distinguish areas of coniferous forest from areas lacking such forests. In mid-March, non-forested ground within the study area is usually covered with snow, which strongly reflects solar radiation in the 0.1-0.7 micron range (Band 5), and therefore appears bright to the Landsat sensor. In contrast, little energy is reflected at this wavelength by vegetation, which appears dark to the Landsat sensor. The first step in the classification process is to separate the scene into two subsets, a low reflectance subset which includes forests and a high reflectance subset which includes unforested, snow-covered areas.

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Ideally, the low reflectance subset would contain all forests and nothing but forests as defined by some arbitrarily selected canopy coverage, and the low reflectance subset would include everything else. The rugged terrain in the study area and the presence of environmental features other than snow and vegetation (e.g. bare rock, open water) preclude a clean differentiation between forest and non-forest based on a single threshold reflectance value.

In the ideal situation of two discrete reflecting surfaces (snow versus vegetation) and flat terrain, a strictly bimodal distribution of Landsat data values would occur. Snow reflects in excess of 90% of incident radiation in Band 5 (O'Brien and Munis, 1975) while vegetation reflects in the order of 5% of incident Band 5 radiation (Kalensky and Wilson, 1975), so it is unlikely that any overlap would be observed.

The histogram of Band 5 values from the March 19, 1979 scene suggests a bimodal distribution with one mode at 25% saturation and the other at full sensor saturation, but all intermediate values are present so no single value gives complete, unambiguous separation. The peak at 25% saturation is interpreted as a manifestation of large areas of water and of forest in the study area. Sensor

saturation occurs because of the predominance of snow and because Landsat lacks the dynamic range to record accurately the reflectance of very bright objects. The many data points with intermediate reflectance values are interpreted as being the result of snow in shadows and of surfaces with reflectances intermediate between vegetation and snow (e.g. rocks or partial snow cover within a pixel). The best reflectance value for separation was judged to be at 40% of saturation.

This value was initially chosen during an interactive session on the image analysis system when the results of various possible cut-off values were viewed on a television monitor. Inspection of the Band 5 histogram confirmed that 40% saturation was a reasonable cut-off value. The low reflectance subset would include all dense canopy forests and other dark features (e.g. shadows, water). The high reflectance subset would contain most snow areas. Intermediate coverage (part snow, part vegetation and mixed coniferous/deciduous forests) would be distributed between the two subsets in a complex pattern according to aspect and percent exposed vegetative cover.

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The objective of the second level classification was to delineate specific environmental themes related to vegetation and wildlife habitat. To accomplish this objective, an automated digital classification was performed on the Landsat data from August 17, 1981 separately for the low reflectance subset and for the high reflectance subset. The result of the second level classification was to assign each pixel in a rectangular shaped subset of the full scene to one and one only environmental theme. A subset of the full scene was used to eliminate unncessary processing of data outside the Homathko drainage. Software limitations in the image analysis system require this subset to be rectangular. Figure 1 shows the location of this subset.

A supervised classification algorithm was used to generate and map themes. This algorithm entails selecting areas of known environmental characteristics and identifying each to the image analysis computer. The computer records the mean and variance for the reflectance values from each of the four Landsat bands within each identified environmental theme. This set of means and variances is called a spectral signature of the theme. After the spectral signature of

each theme has been produced, the computer is instructed to test all other pixels and determine whether the spectral values match any of the identified themes. If so, that theme is assigned to that pixel. If more than one theme fits, then the computer assigns the theme which fits best on the basis of statistical parameters using a Bayesian decision rule. Unmatched pixels are assigned to the "null" theme.

4.4 Ground Truthing

The digital classification produces a map-like image or series of images which identify each pixel as belonging to one of a finite set of "environmental themes". The next step is to establish the relationship between the sets of points mapped as a theme and what actually exists on the ground. This process is conventionally called "ground truthing".

Ground truthing was accomplished during a site visit by David Hawes and Stephan Houseknecht between June 27 and June 30, 1983, inclusive. A helicopter was used to fly over most of the study area and to land the ground truthing crew on or within walking distance of all identifiable themes.

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Table I

ENVIRONMENTAL THEMES USED TO CLASSIFY HOMATHKO STUDY AREA

Theme Label	Description of Training Feature	Used in Forest Class.	Used in Non-Forest Class.
1 Pine	Interior forests of lodgepole pine and Douglas-fir	Yes	No
2 Spruce	Interior forests at higher elevation and with denser canopy than Theme #1	Yes	Yes
3 Hemlock	Coastal forests on slopes in Homathko watershed	Yes	No
4 Mixed-Deciduous	Cottonwood and Cottonwood/Cedar forests in Homathko floodplain	Yes	Yes
5 Snow	Snow	Yes	Yes
6 Glacier	Ice, mixed with till and interspersed by morraines	Yes	Yes
7 Alpine*	Alpine in Potato Range	Yes*	Yes
8 Barrens*	Open areas north of Choelquoit Lake		Yes
9 Young Coniferous	Forests south of Choelquoit Lake	Yes	Yes
10 Coastal Subalpine**	Fen in Homathko floodplain	Yes	Yes
11 Avalanche	Avalanche tracks		Yes
12 Alpine Meadows	Area above treeline		Yes

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* Themes 7 and 8 when lumped together are called "Grasslands" in the text

** The only instance where the major theme revealed (in terms of areal coverage) was different from the theme trained upon.

5.0 RESULTS AND DISCUSSION

5.1 Overview

An image was produced of the August 17, 1981 scene at a scale of 1:250 000 which shows the study area in simulated false color infrared (IMAGE I). Much general information about physiography and general vegetation cover can be gained from examining this image.

5.2 Snow Cover Mapping

5.2.1 Basics of Interpretation of Snow Cover Image

The 1:250 000 scale snow cover image (IMAGE II) is relatively straightforward, except for a few processing artifacts (e.g., stripes in the snow-covered area). The pattern of snowmelt can be inferred from the hue and intensity of the image, because of the way the image was composed. Early melt-off (detected by a darkening of the scene between March and April) has been imaged as blue, mid melt-off (April-May) as red, and late melt-off (May to August) as green. Such inference is described below and mapped at a scale of 1:250 000 in Figure 3. The pattern of snowmelt proved so complex that mapping at a scale of 1:250 000 fails to include much of the relevant information which can be seen on IMAGE II.

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The relatively flat interior lands north and east of the cost mountains provide an example for interpretation of IMAGE II. These lands appear predominantly reddish with grey, tan and purplish variations. This pattern indicates that the area melts off fairly uniformly and completely between mid-April and late May. Grey areas comprise denser forests with more complete canopy cover than are colored areas. Yellowish-tan areas melt off slightly later than pink areas and probably also have canopy coverage intermediate between pink and grey areas. Purple areas begin to melt off slightly earlier than surrounding pink areas and also correspond to wispy clouds present in one of the images. Snow cover variations within the interior appear to be slight and therefore probably insufficient to generate special value wildlife habitat.

5.2.2 Pattern 1 - No Apparent Melt

Areas which are unchanged in terms of snow cover are a neutral grey in color on IMAGE II regardless of their color on other images. Examples are snow and ice fields, ice-free lakes (e.g., north end of Chilko Lake), and closed canopy forests.

Of these, closed canopy forests represent potential winter range for coast black-tailed deer. These forests can be clearly identified based on color (grey), context, and the lack of stripes. Stripes occur as a processing artifact on glaciers and snowfields as a result of sensor saturation, and these stripes assist in differentiating snowfields from forests. Forests are mapped as "f" in Figure 3.

Another grey zone area of special interest is slightly bluish and is found by elevational context near tree line but below the perpetual ice and snow zone. These areas change little and appear to be neither forests nor snowy in the summer scene (IMAGE I). What little darkening occurs happens early, hence these areas appear slightly bluish on IMAGE II. These areas are wind blown prominences which have thin snow which melts early. They are light colored rocks and bare soil or xeric-alpine which are highly reflective in summer. These bluish areas could comprise important habitat for alpine species and are mapped in Figure 2.

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5.2.3 Pattern 2 - March to April Melt

The first pattern represents very early melt-off (March-April). These areas are cyan in color on the images, few in number, and located at low elevations mainly along the Southgate, Klinaklini and Homathko rivers (Figure 3). Within the Homathko drainage, early melt-off areas are found as far upstream as Klattasine Creek. Most of these areas appear to be in the valley bottom associated with poor drainage or seasonal flooding and would not be expected to constitute exceptional ungulate winter range. However, the areas mapped in the vicinity of Scar and Klattasine Creeks are on slopes at high elevation near treeline and would warrant investigation during winter wildlife surveys.

5.2.4 Pattern 3 - April to May Melt

Areas which have melted off between mid-April and late May appear reddish on the image. A large propertion of the image appears reddish because the main melt-off coincides with this time slot, especially for the interior forests previously described as an example of interpretation. Slight purple tinges indicate an earlier beginning to melt-off than the pure reds, and the orange tinged areas continue to darken after the end of May.

Red areas are numerous on the image. A significant observation is that in mountainous terrain, red areas are not found at low elevation in the major valleys, but tend to occur at high elevation in creek headwaters of tributary watersheds. Large contiguous areas of red may well represent winter range for ungulates and can be listed as follows (see figure 3 for complete coverage):

Within the Mosley Creek drainage:

- Scimitar Creek
- Twist Creek
- Crazy Creek
- Five Finger Creek
- Headwaters of Razon Creek
- North and west of Mosley Creek between Bluff Lake and Middle Lake
- North of Mosley Creek at the approximate latitude of Dumbell Lake

Within the remainder of the Homathko drainage:

- Nude Creek and along the Homathko between Mosley and Ottarasko Creeks
- Nostetuko - west side near headwaters
- Nut Mountain near Tatlayoko Lake
- Doran Creek
- Slopes north of Tiedemann Glacier
- Homathko north of Scar Creek
- Headwaters of Heakamie and Jewakwa River

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In addition to these large areas of early melt-off, innumerable small areas exist along ridges throughout the study area. These small areas are too

numerous to list. Most of the listed and mapped Pattern 3 areas are associated with the oversteepened sides of glacially formed valleys. The steepness of the slopes and the presence of thermal inversions appear to limit snow thickness and to speed its disappearance. However, these sites are often sparsely vegetated and relatively unproductive of biomass.

5.2.5 Pattern 4 - March to May Melt

Areas which darkened in the first two intervals would have a combination of blue and red and would appear purplish on the image. Very few such areas were noted, and these were located mainly adjacent to Pattern 2 and in the lower Homathko drainage. Brew Creek appears to be an area which shows earlier than average melt-off.

5.2.6 Pattern 5 - High Elevation Early Melt

An environmental feature which was noted as being potentially significant to wildlife is found in areas of purple which, by inference, begin to melt out earlier than the red areas but which are located elevationally between the red and the very late melting green areas. These areas proved to be nearly vertical, south facing rock walls with sparse vegetation. The distribution of these Pattern 5 areas is closely associated with Pattern 3 areas (Figure 3).

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5.2.7 Pattern 6 - Late Melting Areas

Green and yellow colors on IMAGE II represent the last areas to melt off and are therefore assessed as being poor wildlife habitat.

5.2.8 Snow Melt Summary

Potential wildlife habitat was mapped and ranked prior to winter surveys, and the manuscript forwarded to the wildlife consultants, Environmental Management Associates of Calgary. Potential winter habitat was assessed as being commonly and widely dispersed through the mountainous regions of the study area. In general, the areas located are not in valley bottoms or in the major river

valleys, but tend to be dispersed at mid-elevations near the headwaters of tributary streams. Valley bottoms contained dense coniferous tree cover beneath which snow conditions were not discernible by satellite.

5.3 Vegetation Mapping

A total area of a 547 661 ha has been classified. In the first level classification, 47% of the classified area was in the low reflectance subset and 53% was in the high reflectance subset, each pixel being in one or the other subset.

The purpose of the first level classification was to differentiate forested areas from unforested areas. The information in the March scene is different from the August scene in a coherent fashion - the presence of snow dramatically increases the reflectance except where vegetation protrudes and masks the snow. This purpose has been largely accomplished, but some ambiguity still exists where environmental conditions substantially depart from the archetypes of forest in full sun versus snow in full sun.

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Forest cover can be viewed as a continuum ranging from no forest at all to dense coastal forest. Interacting with this variable is the illumination which can range from full sun to full shade (nothing but backscattering from the sky). The angle between the sun, the satellite, and the surface can profoundly affect the efficiency of measuring backscatter, especially for specular surfaces such as ice or wet snow. Therefore some intermediate canopy coverages are classified as low reflectance while others which may be very similar vegetationally are classified as high reflectance.

5.3.1 Low Reflectance Subset

The results of thematic subclassification of the low reflectance subset are listed in Table I and displayed on IMAGE III. Within this subset 15% of the pixels were in the null class, i.e., did not fit any of the identified environmental themes. Comparison of the distribution of the null class from the low reflectance subset (black on IMAGE III) with maps and with the August Landsat

Table I

AREAL COVERAGE ESTIMATES OF ENVIRONMENTAL THEMES,
LOW REFLECTANCE SUBSET

Theme	Color/Image	Area (ha)	Percent of Subset	Percent of Total
TOTAL AREA CLASSIFIED	-	1 547 661	-	100
Low Reflectance Subset	White	729 752	100	47
Null, incl. water, shadows	Black/III	108 107	15	7
"Coniferous"	Light Green/III	188 951	25	12
"Pine" (older with beetle kill)	Grey/III	132 215	18	8
"Mature Coniferous"	Dark Green/III	128 992	18	8
"Young Pine"	Red/III	62 418	9	4
"Grasslands"	Dark Brown/III	28 157	4	2
"Open Canopy" Sparse trees	Pink/III	27 610	4	2
"Mixed/Deciduous"	Yellow/III	27 525	4	2
"Snow and Ice"	Blue-Grey/III	18 144	2	1
"Alpine & Subalpine"	Dark Purple/III	13 633	2	1

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image (IMAGE I) reveals that the great bulk of what was left in the null class corresponds to water bodies and deep shadows.

The "snow and ice" theme within the low reflectance subset is somewhat of an enigma because snow and ice are typically characterized by high reflectance. The distribution of this theme (blue-grey on IMAGE III) suggests that the change in sun angle between March and August is sufficient to explain this theme. What has occurred is that some areas of snow and ice were in deep shadow in March and in sunshine in August. Thus the 18 144 ha (2% of the subset) is not forested and is probably neither vegetated nor significant as wildlife habitat.

The remaining themes were either vegetated with forests or were clear of snow in March of 1979. Of these, the most prevalent was the "coniferous" theme (light green on IMAGE III) which accounted for [illegible] third of the identified forest (low reflectance subset excluding the null and the snow and ice themes) and 12% of the total classified area. Ground truthing revealed this theme to be a closed canopy coniferous forest dominated by pine, Douglas-fir, true fir or mixture of tree species. The theme is broadly distributed through the area including high-elevation subalpine forests in the coastal mountains, valley bottom forests, and large contiguous areas east of the coast mountains.

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The second most extensive forest cover theme is "pine" (grey on IMAGE III) representing approximately 22% of the forest and 8% of the total classified area (131 215 ha). The "pine" theme is mainly lodgepole pine forests affected by beetle kill. Not all pine beetle kills show as grey, but nearly all grey areas are pine kills. Some areas, e.g., along Mosley Creek, show excellent correlation between ground truth and mapped theme location, but others, e.g., Fraser Plateau, correlate less well with large areas of sporadic beetle kill not appearing on the imagery. The reason for these areas being missed was not determined. The "pine" theme is distributed primarily east of the mountains, but also occurs in some of the dry valleys (e.g., Nemaia Creek).

The third most extensive forest cover theme is "mature coniferous" which accounts for 128 992 ha or 21% of the forest and 8% of the total classified area. The "mature coniferous" theme occurs mainly along valley slopes within the coast mountains and is more prevalent closer to the coast. It corresponds

well to large old stands of hemlock, cedar and Douglas-fir. Ground truthing revealed that forests typical of the "coniferous" theme which lie in partial shadow are erroneously categorized as "mature coniferous" probably because they appear darker. This phenomenon can be taken into account during interpretation.

"Young pine" forest, displayed in red on IMAGE III, covers 62 418 ha, includes 11% of the "forest" and 4% of the total classified area. This theme is prevalent in the drier portions of the interior and is usually closely associated with areas classified as "pine". Ground truthing revealed this theme to be mainly even-aged stands of young lodgepole pine, as yet unaffected by beetles. Other minor occurrences of the "young pine" theme include along roads and in subalpine areas, where it undoubtedly represents a different but undetermined environmental feature.

PRELIMINARY

The "grassland" theme (dark brown on IMAGE III) occurs primarily in the driest portions of the classified area, i.e. north of Choelquoit Lake, along upper Mosley Creek, and in the Nemaia Valley. It accounts for 28 157 ha or 5% of the forest and 2% of the total area. Ground truthing revealed this theme to be primarily grasslands and sparsely treed rangeland. Roads, airstrips, and what appears to be patches of cleared ground also fall within this theme. It is surprising that low elevation grasslands comprise part of the low reflectance subset. The most plausible explanation is that because of the low snowfall and early meltoff which maintains these ecosystems, these areas were largely free of snow on March 19, 1979.

The "open canopy" theme (purple on IMAGE III) accounts for 27 610 ha which is 5% of the forest and 2% of the total classified area. The "open canopy" theme represents mainly scraggly coniferous forest on thin rocky soils with exposed rock outcrops. These forests are common in some watersheds, e.g. Mosley Creek between Middle and Bluff lakes, and is broadly distributed in the subalpine. The purple color denoting this environmental theme also seems to be associated with streams and valley bottoms in the interior, but these areas were not ground truthed.

"Mixed/deciduous" theme (yellow on IMAGE III) accounts for 27 525 ha or 5% of the forest and 2% of the total area. This theme is found in the floodplain and south-facing slopes of the Homathko River, at treeline throughout the mountains, and in scattered patches amidst the "coniferous" theme. In the interior it is nearly always aspen forest. Near the coast, it could be alder, aspen (uncommon), cottonwood, mixed alder and conifers, mixed cottonwood and conifers (cedar), or cedar forest on slopes with a southern to eastern exposure.

The last predominant theme in the low reflectance subset is the "alpine and subalpine" theme (dark purple on IMAGE III) which covers only 13 633 ha or 2% of the forest and 1% of the total area. This theme is uncommon in the low reflectance subset as it would normally be snow covered in March. This one theme was not well documented during the ground truthing exercise because it is relatively uncommon, it occurs dispersed throughout high and rugged terrain where definite ground location is difficult, and because the few areas located were not particularly distinctive. In all probability this theme consists of edge effects and shifting shadows and is of little environmental consequence. The exception to this rule would be alpine and subalpine areas which were included in the low reflectance subset because they were free of snow in March, 1979. Thus, the intersection of this theme with the Pattern 1 areas in the snow melt image (IMAGE II) could prove to be locally significant wildlife habitat. Two such areas were noted, one on the south slope of Mt Nemaia and one at the headwaters of one of the tributaries of Razor Creek. The Mt Nemaia site was visited during the ground truthing and proved to be an extremely steep mountaintop with exposed and rapidly eroding reddish brown soil and no vegetation. It is unlikely to have much significance to wildlife. The Razor Creek site was not visited but seems too small to be of any regional significance to wildlife.

PRELIMINARY

5.3.2 High Reflectance Subset

The results of the thematic classification of the high reflectance subset are presented in Table II and IMAGES IV and V. (Two images were used to enhance visual discrimination among themes.) This subset is expected to contain all areas covered by ice or snow in March except those in full shade. Also

included in this subset would be areas of partial vegetative cover where a little exposed snow has substantially increased the reflective value of the whole pixel.

The largest single theme within the high reflectance subset was "snow and ice" (grey on IMAGE IV, brown on IMAGE V). This theme coincides with the extensive snow and ice fields of the coastal mountains, and covers an estimated 296 011 ha which is 19% of the total area and 36% of the high reflectance subset. The snow and ice theme includes glaciers and also the associated bare rocks and exposed glacial till surrounding or scattered upon the active glaciers.

A significant area (232 482 ha or 28% of the subset and 15% of the total) remained unclassified (white on IMAGE V). This proportion was unusually high compared with other thematic classifications we have done, but was explained by ground truthing. Most unclassified areas appeared in mountainous terrain immediately adjacent to the snow and ice theme. During the site visit we would see that newly exposed rock would classify with the glaciers, but that older, weathered rock bordering the perpetual ice and snow was missed by all themes and remained unclassified (i.e., "null" in Table II.) These exposed and weathered rocks are darkened with age by lichen encrustations and cover extensive areas above treeline. Some additional unclassified areas consisted of water bodies which were ice covered in March, 1979. Together the "snow and ice" and the "null" themes are considered to be unvegetated (i.e., they contain few or no vascular plants) and amount to 64% of the high reflectance subset.

PRELIMINARY

The "alpine" theme (blood red on IMAGE V) is extensive and accounts for 105 510 ha or 13% of the high reflectance subset and 7% of the total classified area. Its distribution reveals a significant change in climate within the alpine zone as one moves from the coast to the interior. Most of the "alpine" theme occurs north and east of an imaginary line drawn through Middle Lake and the south end of Chilko Lake, where most of the area above treeline classifies into the "alpine" theme. Coastwards (southwest) of this imaginary line much area exists above treeline, but little of it classifies as "alpine"; "snow and ice" and "null" themes predominate instead.

Ground truthing revealed the "alpine" theme to consist primarily of spare low-growing herbaceous and woody vegetation interspersed with exposed soil and lichen-covered rocks. The "alpine" theme also occurs in a few locales well below treeline, e.g., in some recent logging clearcuts. Although the genesis of alpine tundra and logging clearcuts is vastly different, the physiognomy is similar: both consist of sparse, low-growing herbaceous and woody vegetation interspersed with exposed soil. Thus, the satellite sensors see them as being essentially similar.

Not unlike the "alpine" theme is the "alpine barrens" theme (yellow on IMAGE IV). "Alpine barrens" is not extensive (22 044 ha, 3% of the high reflectance subset, and 1% of the total classified area), and it is associated with the "alpine" theme in terms of both distribution and description. "Alpine barrens" is also a mixture of alpine vegetation and exposed soil, but the vegetative cover is sparser and the soil tends to be reddish-brown or ochre in contrast to the black of the organic-rich soils of the "alpine" theme. On some ochre-colored soils, vegetation appeared from the helicopter to be entirely lacking (i.e., south-facing slopes of Mt Nemaia), but some vegetative cover was noted on most areas of "alpine barrens". This theme also occurs at low elevation where it corresponds to nearly bare soil with some sparse vegetative regrowth (i.e., very recent logging, recent glacial retreated, and exposed alluvial outwashes near the confluence of Jawakwa Creek with the Homathko River.

PRELIMINARY

The "alpine meadows" theme (pink on IMAGE IV) also occurs at high elevation and corresponds primarily to two distinct environmental entities: lush alpine meadows on mountaintops (e.g., Potato Range) and dense shrubs on steep slopes in glacial valleys. These two variants can be differentiated based on content information from a topographic map. These two subthemes appear to have no vegetative affinities and probably have similar spectral signatures by mere coincidence. The "alpine meadow" theme covers 19 097 ha which is 2% of the high reflectance subset and 1% of the total classified area.

The "avalanche" theme has a similar spectral signature to the "alpine meadows" theme and is vegetatively similar to the shrub on steep slope variant of that theme. "Avalanche" (red on IMAGE IV and turquoise on IMAGE V) also consists

of shrubs (mainly slide alder) on steep slopes, but is confined almost exclusively to avalanche chutes. As may be expected, the "avalanche" theme occurs in the subalpine in steep-sided valleys in regions of heavy snowfall (e.g., it is more prevalent towards the coast). The "avalanche" theme appears mainly on south and east facing slopes and less frequently on the corresponding north and west facing slopes. This pattern was confirmed in the field and probably reflects local climatic patterns predisposed to avalanches. During field checking some avalanche chutes were observed on steep north and west facing slopes, especially in cirques at the head of glacial valleys, which were in shadow and therefore misclassified. "Avalanche" theme covers only 13 996 ha or 2% of the high reflectance subset and 1% of the total classified area.

A theme which occurs primarily at treeline near the coast has been termed "coastal subalpine" (greenish-yellow on IMAGE V). The heavy snowfall, rugged terrain and shallow, rocky soils within the coastal mountains preclude a sharp treeline. Instead, with increasing elevation the mountain hemlock trees gradually thin out revealing evergreen and deciduous shrubs, icy pools, lichen-covered rocks, and ultimately permanent snow patches to the satellite. This theme covers 42 290 ha, or 5% of the high reflectance subset and 3% of the total area. Within this theme, a substantial-sized fen in the Homathko floodplain near sea level also occurs. The near identity of the spectral signatures of the coastal subalpine and the fen is considered to be a mere coincidence.

PRELIMINARY

In the interior, the discontinuous forest near treeline also appears as a distinct theme within the higher reflectance subset, the "subalpine parkland" theme (green on IMAGE IV). Ground truthing revealed this theme to be primarily a parkland complex of conifers (many with Krummholz 'skirts'), heather, deciduous shrubs, and herbaceous alpine-type vegetation. This theme is distributed primarily in the subalpine of the interior and accounts for only 17 394 ha or 2% of the high reflectance subset and 1% of the total classified area.

Two themes occur within the high reflectance subset which are typical of coniferous vegetation, "coniferous" (pink on IMAGE V) and "young coniferous" (pastel blue on IMAGE V). A possible explanation for this phenomenon is that the vegetation is in fact coniferous and was masked by a highly reflective cover

on March 19, 1979. Another possible explanation is that the vegetation is not coniferous trees, but has essentially the same spectral signature. Ground truthing indicates that most supposedly coniferous areas were in fact coniferous. Careful examination of the images revealed that some forest had been erroneously placed in the high reflectance subset because of cloud cover on March 19, 1979. These clouds occur in three patches: one in the hills north of Choelquoit Lake, one betwen Tsuniah and Chaunigan lakes and one on Vedan Mountain. All of these areas are small in size and peripheral to the main focus of the Homathko wildlife studies, so their erroneous placement within the high reflectance subset is of little consequence.

Other areas with coniferous-type signatures occurred in patches in the interior. During ground truthing these were seen to consist of a dense growth of low conifers (lodgepole pine) which have established following recent forest fires. These conifers may have been covered in snow in March 1979 or may have grown substantially between March 1979 and August 1981. The "coniferous" and "young coniferous" themes also occur in narrow strips near treeline throughout mountainous terrain. These strips correspond to subalpine parkland made up by patches of conifers, shrubby vegetation (either Krummholz conifers or more often needle-leafed shrubs such as heather), or of alpine meadow vegetation. Both themes have similar distributions and the ground truthing exercise was sufficiently detailed to reveal consistent differences between these two "coniferous" type themes. Combined, these themes cover 69 084 ha or 8% of the high reflectance subset and 4% of the total classified area of which approximately half is coniferous regrowth and half is subalpine shrubs.

PRELIMINARY

5.4 Wildlife Habitat

Extrapolation of wildlife habitat has been based on sample information provided in January 1984 by Environmental Management Associates (EMA) about wildlife occurrence within the Homathko study area. The objectives of using Landsat to map wildlife habitat and of assessing the accuracy of such mapping are antagonistic. The same data cannot be used for both purposes. Threfore, by agreement, EMA was to provide Pegasus with only a portion of the information about wildlife occurrence. This information was in the form of maps which showed one or two documented areas of winter range for:

(a) moose,
(b) "interior" goats,
(c) "coastal" goats, and
(d) "interior" deer.

PRELIMINARY

These mapped areas are assumed to constitute typical winter range for each species or ecotype and we have characterized this "typical winter range" in terms of snow cover (IMAGE II) and environmental themes (IMAGES III, IV & V). Subsequently, areas within the Homathko drainage with similar environmental characteristics were identified and mapped at a scale of 1:250 000 (Figure 4).

The interpretation can only be as good as the information upon which it is based, and the scarcity of input data makes the interpretation subject to error. Errors of omission occur if several environment configurations are suitable as winter range for a species, but not all are identified to the interpreter. The result of this type of error would be that the mapping would be accurate but incomplete. Moose, in particular, is a species likely to fit into this category. The one "type" area we were given is in the subalpine zone, and it is possible that moose could also utilize some lower elevation sites as winter range.

Another type of error occurs if an inappropriate or an overly broad inference is made as to what constitutes wildlife habitat. The result of making type type of error is that areas would be mapped as winter range which are not.

The same error would be encountered if the satellite imagery lacks discriminating power for features of importance.

Only one patch of moose winter range was identified to us (Figure 4) and a large area was similar to it in terms of snow cover (Patterns "3" and "5" in Figure 3). The concurrence of the snow cover with the subalpine vegetation theme considerably reduced the area mapped as moose range. The mapping of moose winter range (Figure 4) appears to correlate with shrubby or sparsely treed subalpine areas which melt off moderately early in the spring. Several areas exist, notably Five-Finger Creek, the slopes northwest of Middle Lake, the headwaters of creeks on the north side of Blackhorn and Razorback mountains, and the slopes west of Tatlayoko Lake which have extensive areas of early snow disappearance, but lack the diagnostic vegetation patterns used to define "moose winter range". These areas are the ones most likely to contain unmapped moose winter range.

PRELIMINARY

Upon analysis, no consistent environmental difference could be found between "interior" and "coastal" goats, but there did appear to be a "high elevation" and a "low elevation" pattern in the coastal region. Therefore, goat habitat has been mapped accordingly. The primary criterion used for mapping high elevation goat winter range is the presence of Pattern "1a" (Figure 3). While this pattern would not define goat winter range, it appears to include most of the better areas. The low elevation habitat is mapped as areas of predominately "Mixed/Deciduous" forest (Yellow in IMAGE III), mixed with non-forest themes (White on IMAGE III), and immediately adjacent to a Pattern "5" or "1a" area.

Deer winter range appeared to be associated with low snow (Pattern "3" and "3/f" on Figure 3) in a vegetationally diverse area which contained several environmental themes including forested and non-forested themes in a relatively small area. Habitats so characterized occurred mainly in a belt west of Tatlayoko Lake and have been mapped as probable critical habitat for deer in Figure 4.

The mottled vegetation pattern characteristic of deer winter range occurs over a wider area of more dense forest and less distinct early snow melt and has been mapped as "less critical" habitat for deer in Figure 4. The idea is that this large area would be only marginal winter habitat for deer within which small patches of good deer winter range would exist for localized snow and vegetation conditions. The "less critical" habitat mapping has been extended to the coastal forests where vegetation and snowmelt patterns are somewhat similar to known deer winter range in the interior. Admittedly, such mapping is only conjecture, but it may serve as a starting point for coastal blacktail deer habitat evaluation.

Sheep habitat has not been mapped. One reason is that a habitat type location for sheep habitat was not forwarded by the wildlife consultants presumably because few if any sheep were encountered during field studies within the study area. Sheep habitat could be inferred from a knowledge of sheep biology and mapped based on the satellite imagery. However, it was not part of the terms of reference to map hypothetical habitats for species which may be introduced or re-introduced to the study area. The satellite imagery indicates that hypothetical sheep habitat exists in the most arid (i.e., easterly) part of the alpine in areas currently used for summer livestock pasture.

PRELIMINARY

6.0 CONCLUSIONS AND RECOMMENDATIONS

The study area presents many difficulties to assessment and mapping of vegetation and wildlife habitat. The extremely rugged terrain combines with strong and varied weather patterns to produce a tremendously complex pattern of vegetation, land forms, and micro-climatic conditions within the given geographic area. It is very difficult to document environmental equivalences among subareas. One purpose of the Landsat based study was to document environmental attributes and patterns not readily discernible from the ground and another purpose was to map wildlife habitat based on these patterns. The program was at least modestly successful in achieving these objectives.

The necessity of using a multi-year analysis rather than the preferred one-year serial analysis seems to have reduced the discriminatory capability of the methodology, but has not invalidated it nor produced significant methodological artifact. The results of the snow cover mapping look reasonable. The patterns revealed are generally consistent with what one would intuitively expect to occur.

PRELIMINARY

Variations from intuitive expectations are important if they are not processing artifacts. One such variation is for extensive areas of early melt-off to occur along the steep-walled headwaters of tributary streams at subalpine elevation. As these early melt-off areas are inferred to have potential significance as winter range, one would expect the subalpine of tributary streams to have a greater significance to local ungulate populations than the lowlands do. If true, this conclusion may have a strong bearing on impact assesment of hydroelectric development.

Vegetation interpretation and mapping at 1:250 000 scale was successful. Ground truthing suggested that more detailed mapping could be achieved with the satellite imagery accompanying this report. Ordinarily, vegetation is difficult to classify in rugged terrain because of the strong interaction between reflectance values, incident solar radiation, and slope and aspect. A two-step multi-temporal process is responsible for the relatively good performance of the vegetation classifier and is a great improvement over the conventional one-step process. Interpretation of vegetation from the thematic maps requires consideration of

elevation, slope, aspect and biogeoclimatic zone to obtain the most detailed and accurate results. In theory, a digital terrain model would vastly improve the process of classifying vegetation in rugged, mountainous terrain. Use of the vegetation themes during more detailed vegetation mapping is recommended as a supplement to air photo interpretation.

The results of this project were not as immediately and obviously satisfying as they could have been. A similar project , in the Rocky Mountains in north-eastern B.C., resulted in a few discrete areas which were differentiated on the basis of early snow melt and which were documented as significant ungulate winter range (Jaques and Hawes, unpublished). Thus the correlation between early snow melt and critical ungulate winter range was established and the lack of such early snow melt areas elsewhere could be taken as an indication of an absence of critical ungulate winter range. In the present study, the moderating influence of the Pacific Ocean and the intricate movement of weather patterns through the mountains have made the snowmelt patterns far more complex. There is, therefore, no obvious over-riding pattern and the results are difficult to interpret. The correlation between snow depth and date of melt-off is less reliable in the coast region because extremely heavy snowfalls can occur and then be rapidly melted by warm Pacific rain-storms. The high energy flux of coastal locations makes interpretation difficult.

PRELIMINARY

Information on wildlife distribution available to the author to assess the relationship between the satellite interpretation and critical winter range in the Homathko drainage is limited. Therefore, no definitive conclusion can be reached by this author as to the success of the technique in documenting attributes of critical wildlife habitat. The value of the imagery and its interpretation potential is a function of knowledge of species biology. The imagery accompanying this report is anticipated to have value and to reveal new information to biologists familiar with local wildlife.

7.0 LITERATURE CITED

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PRELIMINARY

8.0 GLOSSARY OF REMOTE SENSING TERMS

ALGORITHM - A rule of procedure for solving a problem.

BAND - A defined range of frequency of light, also the set of reflectance values from that frequency range. Landsat MSS data consist of four discrete bands conventionally labelled 4, 5, 6 and 7 and having frequency boundaries of 0.5 - 0.6 microns, 0.6 - 0.7 microns, 0.7 - 0.8 microns, and 0.8 - 1.1 microns respectively.

BAYESIAN DECISION RULE - A mathematical procedure based on probability density estimates and minimization of combined errors. It is used in remote sensing to assign a given value or set of values to the class of values to which it most likely belongs.

BULK PROCESSING - The production of imagery having only rudimentary or preliminary corrections to systems-induced image artifacts.

CCT - Computer Compatible Tape

CLASSIFICATION - The process of grouping and categorizing pixel locations based on the statistical similarity/dissimilarity of reflectance values.

COMPUTER COMPATIBLE TAPE - A transportable magnetic storage medium capable of being mounted on a conventional computer installation.

DIGITAL IMAGERY - The storage of visual information as arrays of numbers rather than as pigments on a photograph or phosphors on a cathode ray tube.

DIGITAL PROCESSING - The computer-assisted manipulation of digital imagery.

DIGITAL TERRAIN MODEL, or DTM - A mathematical representation of a topographic surface in terms of elevation, slope, and aspect.

GEOMETRIC CORRECTION - The process of removing distortions introduced into imagery. Geometric correction in this paper refers to the process of conforming satellite imagery to orthic map projections.

GROUND CONTROL POINTS - Points of known geographic location which can also be identified on the satellite imagery and which are used in the geometric correction process.

GROUND TRUTH - The known environmental situation which is used to generate or evaluate an interpretation scheme.

IMAGE ANLYSIS SYSTEM - A computer system specialized for the processing and visual display of digital imagery.

IMAGERY - A generalized term referring to information which can be visually encoded.

PRELIMINARY

LANDSAT - A series of U.S. satellites, the first of which was launched June 23, 1972, which were intended to provide systematic, repeated views of the earth for civilian purposes.

MICRON - A unit of length equal to one-thousandth of a millimetre.

MSS - Multi-spectral scanner.

MULTI-SPECTRAL SCANNER - A device which scans several different frequencies simultaneously. Also, the specific scanner used in the Landsat series of satellites (see BAND).

MULTI-TEMPORAL - Refers to combining of imagery from different satellite passes.

PIXEL - The smallest discernible picture element in a digital image. A pixel can be conceptualized as the smallest unique spot on the ground viewable by the satellite. In Landsat MSS imagery, a pixel is 79 m square.

PRECISION PROCESSING - The production of imagery which has most of the system induced image artifacts removed. NAME imagery which has been radiometrically and geometrically corrected.

RADIOMETRIC CORRECTION - The process of correcting systematic errors to the numeric values of digital imagery. For Landsat data, radiometric correction consists primarily of correcting for inequalities of sensor element sensitivities. Uncorrected imagery has distinctly striped appearance.

REFLECTANCE VALUE - The number associated with a given band number and pixel location and which is a function of the amount of backscattered light in that frequency range from that location.

SATURATION - The maximum recordable reflectance value above which increased backscatter cannot be measured.

SENSOR - A device that responds to a physical stimulus (electromagnetic radiation) and transmits a resulting impulse for measurement.

SIGNATURE - The combination of reflectance values used to characterize and categorize pixels during classification.

SPECTRAL VALUE - Reflectance value.

SPECULAR SURFACE - A surface which is smooth and reflects light in a mirror-like fashion.

PRELIMINARY

APPENDIX A

TERMS OF REFERENCE - WILDLIFE AND LANDSAT STUDIES

Specific terms of reference for preliminary Landsat studies were included with those written for wildlife. These terms of reference are provided in their entirety in this appendix.

Those items relating specifically to Landsat studies are listed under "Delineation of Areas Which Have Potential for Ungulate Wintering". Study item 5, however, was revised to exclude the Chilko and Taseko River drainage basins.

PRELIMINARY

DETAILED STUDY REQUIREMENTS

Limited wildlife data exists for the project areas, and little is known about the following specific concerns:

1. Extent and distribution of critical wintering habitat for ungulate populations.

2. Potential carrying capacity of habitats in the study area.

3. Utilization, during both summer and winter, of areas affected by the proposed development during exploration, construction and operation.

4. Extent of use of mud and ice flats between the Taseko lakes during fall ungulate migrations.

5. Extent of current local, regional and provincial use of large mammals and furbearers.

6. Extent and use of wetlands habitat by waterfowl.

Therefore, the objectives of the Phase I feasibility studies are:

(i) Delineation of Areas Which Have Potential for Ungulate Wintering

1. Use serial analysis of Landsat data to define areas which have snow cover, slope, aspect, and vegetation indicating potential value as winter range for ungulates. Use first areas bare of snow as the first key to potential.

2. If feasible, develop and apply criteria which rank or classify the areas identified.

3. Map the identified areas on B.C. Hydro base map at 1:250 000 scale.

4. Provide a brief physical and biological description of each site or group of sites.

5. The study area shall encompass the drainage basins of the Homathko, Mosely, Chilko and Taseko rivers to an arbitrary northern limit at the latitude of Tatla Lake.

PRELIMINARY

(ii) Inventory of Wildlife Resource

1. Survey the above identified potential ungulate winter areas using standard aerial and ground techniques. Dense forest cover over much of the study area will favour ground survey methods.

2. Inventory wildlife use of areas directly affected by flooding, road construction, drilling activities, borrow pit excavation and other construction activities. Provide a draft map at 1:250 000 or larger depicting critical winter

habitat, migration routes, calving areas, concentration areas, or other incidental information.

3. Compile existing data on wildlife populations and carrying capacities in the study area. Record all incidental wildlife observations providing date, time, location and vegetation type.

4. Carry out a generalized survey of habitat quality and animal abundance within the area of direct project impact. Concentrate efforts on sensitive species such as grizzly bear, black bear, mountain goat, and mountain sheep.

5. Establish use by species and by season of the flats between the Taseko lakes. If possible, relate to weather severity and ice conditions on the lakes.

6. Survey known salmon streams during spawning season to determine use by and importance to grizzly bears.

7. Provide a preliminary inventory of utilization of study area wetlands by waterfowl.

8. Interview local guide outfitters, hunters, and Fish and Wildlife personnel to ascertain concentration areas, incidental observations, problem areas and use areas for harvest or viewing of wildlife.

(iii) Assessment of Potential Impacts

1. Based on existing wildlife information supplemented by limited field observations and professional judgement concerning habitat quality, determine the probable project-related loss to wildlife populations and carrying capacity. Relate this evaluation to the alternative project schemes.

PRELIMINARY

2. Review trapline harvest and game harvest questionnaire results (available from B.C. Hydro) and assess potential for impact.

PRELIMINARY